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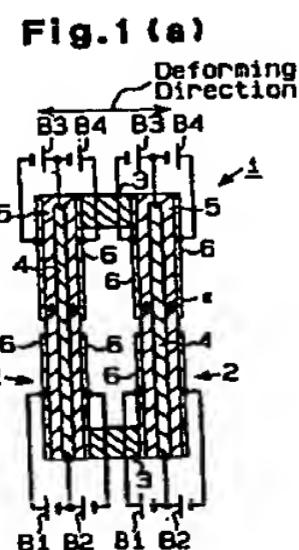
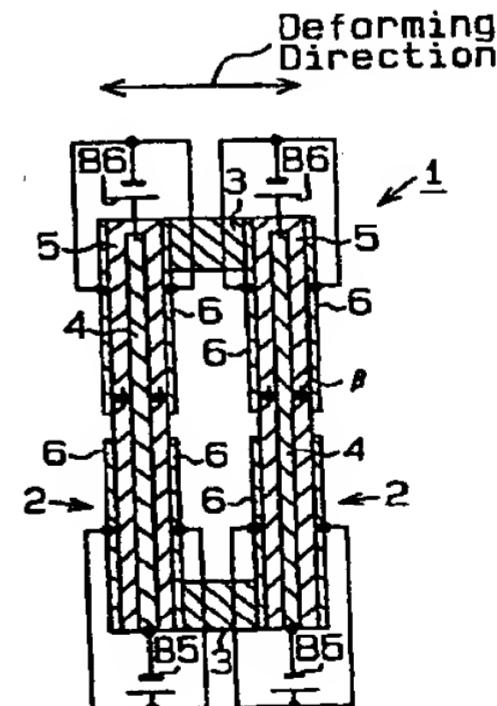
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(54) **PARALLEL PLATE STRUCTURE PROVIDED WITH PZT THIN-FILM BIMORPH AND METHOD OF FABRICATION THEREOF**

(57) A parallel plate structure (1) is provided with a pair of bimorph piezoelectric elements (2) and prismatic insulation spacers (3) inserted between the piezoelectric elements (2) at the upper and lower ends thereof for cementing the piezoelectric elements (2) together via the spacers (3). Each piezoelectric element (2) comprises a planar base material (4) of titanium, PZT thin films (5) formed on both sides of the base material (4) by the hydrothermal method, and electrode films (6) formed on the PZT thin films (5). The base material (4) is 20 μ m thick and the PZT thin films (5) are several μ m thick, while the aluminum electrode films (6) are several μ m thick.

Fig. 1 (b)



Description

TECHNICAL FIELD

[0001] The present invention relates to a parallel plate structure provided with a PZT (lead (Pb) Zirconate Titanate) thin-film bimorph and method of fabrication thereof, and more particularly, to structures used as piezoelectric actuators.

BACKGROUND ART

[0002] A bimorph, which is known in the prior art, includes a plate-like substrate, two PZT devices (lead zirconate titanate: ceramics containing a solid solution of lead titanate and lead zirconate), which are formed on the front and rear surfaces of the substrate and which function as piezoelectric devices, and electrodes formed on each PZT device. Voltage is applied to both of the PZT devices so that one of the PZT devices expands while the other contracts. Since this deforms the bimorph entirely in a certain direction, the bimorph is used as an actuator.

[0003] However, when employing preformed PZT devices, it is difficult to make the devices thinner in subsequent processes. Accordingly, the production of a more compact bimorph is difficult. Furthermore, a lot of time is required to adhere the PZT devices to the front and rear surfaces of the substrate. This lengthens the fabrication time of the bimorph.

[0004] Additionally, since the bimorph is formed as a monolithic single plate, the bimorph is apt to deform in an undesirable direction. This results in a shortcoming in which the bimorph twists and does not deform accurately.

DISCLOSURE OF THE INVENTION

[0005] Accordingly, it is an objective of the present invention to provide a parallel plate structure having a PZT thin-film bimorph that deforms by a large degree.

[0006] Another objective of the present invention is to provide a parallel plate structure having a PZT thin-film bimorph that is optimal for mass-production, can be made more compact, and resists twisting.

[0007] A further objective of the present invention is to provide a parallel plate structure having a PZT thin-film bimorph that has superior productivity.

[0008] A parallel plate structure, which is provided with a bimorph, according to the present invention, has a thin PZT thin-film formed on a first and second surface of a titanium substrate. Thus, the bimorph is more compact. This, in turn, makes the entire structure more compact. Furthermore, the parallel plate structure is a duplex structure in which a pair of bimorphs are superimposed by way of a spacer. Hence, the structure has improved rigidity and resists twisting.

[0009] When deforming the structure, voltage hav-

ing opposite polarities is applied to adjacent electrodes on a first surface of each bimorph. As a result, the portion of the PZT thin-film to which an electric field in the polarity direction is applied contracts, while the portion of the PZT thin-film to which an electric field in the direction opposite the polarity direction is applied expands.

[0010] Due to the application of the same voltage, each bimorph deforms in the same direction. Due to the application of voltage having different polarities to the adjacent electrodes on each surface of each bimorph, the portions of the PZT thin-film to which the voltage of different polarities are applied deform in opposite directions. As a result, since the portions of the PZT thin-film corresponding to the adjacent electrodes deform in opposite directions, the structure is bent in an S-shaped or reversed S-shaped manner and deformed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Fig. 1(a) is a cross-sectional view showing the application of voltage to a parallel plate structure, which is provided with a PZT thin-film bimorph, according to an embodiment of the present invention;

Fig. 1(b) is a cross-sectional view showing further application of voltage to the structure of Fig. 1(a);

Fig. 2(a) is a cross-sectional view showing a deformed state of the structure;

Fig. 2(b) is a cross-sectional view showing a further deformed state of the structure;

Fig. 3 is a cross-sectional view showing a substrate;

Fig. 4 is a cross-sectional view showing the substrate covered by a PZT thin-film;

Fig. 5 is a cross-sectional view showing the substrate on which electrode films are formed;

Fig. 6 is a cross-sectional view showing a piezoelectric device on which the electrode films are patterned;

Fig. 7 is a perspective view showing the piezoelectric device of Fig. 6;

Fig. 8 is an exploded perspective view showing the assembly of a parallel plate structure;

Fig. 9 is a perspective view showing the assembled parallel plate structure;

Fig. 10 is a perspective view showing the structure

of Fig. 9;

Fig. 11 is a perspective view showing a structure provided with a bimorph of a comparative example;

Fig. 12 is a cross-sectional view showing the structure of Fig. 11 in a deformed state;

Fig. 13 is a schematic view showing the structure in a parallel plate actuation mode; and

Fig. 14 is a schematic view showing the structure in a simple bending actuation mode.

BEST MODE FOR CARRYING OUT THE INVENTION

[0012] A parallel plate structure provided with a PZT thin-film bimorph according to an embodiment of the present invention will now be described with reference to Figs. 1 to 10. The thicknesses of each member shown in the drawings are exaggerated for illustrative purposes.

[0013] As shown in Figs. 1(a) and (b), a parallel plate structure 1 includes a pair of plate-like piezoelectric devices 2, or bimorphs, and rectangular column-like insulating spacers 3, which are arranged between the piezoelectric devices 2. The spacers 3 connect the piezoelectric devices 2 at the upper and lower ends of the structure 1 and are made of an insulating material to prevent short-circuiting between the piezoelectric devices 2.

[0014] Each piezoelectric device 2 includes a plate-like titanium substrate 4 having uniform thickness, a PZT thin-film 5 formed on the two sides of the titanium substrate 4, and pairs of upper and lower electrode films 6 formed on each PZT thin-film 5. The electrode films 6 are insulated from each other. One electrode film 6 extends from one end of the associated PZT thin-film 5 substantially to the middle portion of the PZT thin-film 5, while the other electrode film 6 extends from the other end of the PZT thin-film 5 substantially to the middle portion. Each electrode film 6 occupies nearly half the area of the associated PZT thin-film 5. The substrate 4 has a thickness of 20 μ m, while the PZT thin-film 5 has a thickness of several tens of micrometers. The electrode films 6 are made of aluminum and have a thickness of several micrometers.

[0015] When using the structure 1 as an actuator, dc power sources B1-B4 are connected to the structure 1 as shown in Figs. 1(a) and (b). In Fig. 1(a), the polarity direction of the PZT thin-film 5 is indicated by arrows α . The power sources B1, B2 are connected in series. The positive terminal of each power source B1 is connected to the lower left electrode film 6 of the associated piezoelectric device 2. The negative terminal of each power source B2 is connected to the lower right electrode film 6 of the associated piezoelectric device 2. The contact between the power sources B1, B2 is connected to the

associated titanium substrate 4.

[0016] Like the power sources B1, B2, the power sources B3, B4 are connected in series. The positive terminal of the power source B4 is connected to the upper right electrode film 6 of the associated piezoelectric device 2, as viewed in Fig. 1(a). The negative terminal of the power source B3 is connected to the upper left electrode film 6 of the associated piezoelectric device 2. The contact between the power sources B3, B4 is connected to the associated titanium substrate 4.

[0017] The connection between the contact of the power sources B1, B2 and the titanium substrates 4 and the connection between the contact of the power sources B3, B4 and the titanium substrates 4 apply a uniform electric field to the PZT thin-film 5 on each side of the titanium substrates 4. However, the contacts are not required to be connected to the substrate 4 as long as each PZT thin-film 5 has the same thickness. The power sources B1-B4 have the same voltage, which is applied to the PZT thin films 5 by the electrode films 6. Voltage having opposite polarities is applied to the upper and lower portions of each piezoelectric device 2.

[0018] When the lower end (basal end) of the structure 1 is fixed to a base (not shown) and voltage is applied to the structure 1 as shown in Fig. 1(a), the portion of the PZT thin-film 5 to which an electric field is applied in the polarity direction expands in the polarity direction and contracts in the direction perpendicular to the polarity direction. On the other hand, the portion of the PZT thin-film 5 to which an electric field is applied in the direction opposite the polarity direction contracts in the polarity direction and expands in the direction perpendicular to the polarity direction. As a result, the structure 1 bends to the left at its lower portion and bends to the right at its upper portion as shown in Fig. 2(a). Hereafter, the expansion and contraction of the PZT thin-film 5 in the direction perpendicular to the polarity direction will be described.

[0019] When voltage having a polarity opposite that of Fig. 1(a) is applied to the PZT thin films 5, the upper right portion and lower left portion of each piezoelectric device 2 expands, while the upper left portion and lower right portion of each piezoelectric device 2 contracts. As a result, the structure 1 bends to the right at its lower portion and bends to the left at its upper portion as shown in Fig. 2(b).

[0020] In Figs. 2(a) and (b), the electrode films 6 are not shown. The compressed portions 5a of the PZT thin-films 5 are shown by the hatch lines extending downward from right to left, and the expanded portions 5b are shown by the hatch lines extending downward from left to right.

[0021] In Fig. 1(b), the polarity direction of the PZT thin-film 5 is indicated by arrows β . As shown in the same drawing, the negative terminal of each power source B5 is connected to the associated substrate 4. The positive terminal of each power source B5 is connected to the electrode films 6 on each side of the lower

portion of the associated piezoelectric device 2. The negative terminal of each power source B6 is connected to the associated substrate 4. The positive terminal of each power source B6 is connected to the electrode films 6 on each side of the upper portion of the associated piezoelectric device 2. When each electric source B5 applies a positive potential to the associated PZT thin-film 5, the lower right portion of the PZT thin-film 5 expands, while the lower left portion of the PZT thin-film 5 contracts (deforming to the left as viewed in Fig. 1(b)). When each electric source B6 applies a negative potential to the associated PZT thin-film 5, the upper right portion of the PZT thin-film contracts, while the upper left portion of the PZT thin-film 5 expands. Accordingly, the structure 1 bends to the left at its lower portion and bends to the right at its upper portion as shown in Fig. 2(a). If the polarity direction of the PZT thin-films 5 is β , the same deformation amount as that of Fig. 1(a) is obtained with half the voltage of the power sources B1-B4 of Fig. 1(a).

[0022] Furthermore, when a voltage having a polarity opposite to that of Fig. 1(b) is applied to the PZT thin-films 5, the structure 1 bends to the right at its lower portion and bends to the left at its upper portion as shown in Fig. 2(b).

[0023] The manufacturing process of the structure will now be described with reference to Figs. 3 to 10.

[0024] As shown in Fig. 3, a titanium base material 4A is prepared. The base material 4A is plate-like and has a uniform thickness. The base material 4A has an area equal to that of a plurality of the substrates 4 of the structure 1. The base material 4A is first cleaned with acid or the like. A mask M is then applied to one end (corresponding to the basal side in Fig. 1) of the base material 4A. The mask M is formed from a synthetic resin or from a metal other than titanium by employing a physical film formation process, such as sputtering or vacuum deposition.

[0025] Afterward, as shown in Fig. 4, a PZT thin-film 5 is formed on both sides of the base material 4A using a hydrothermal process. The hydrothermal process includes two stages as described below.

[First Stage]

[0026] The base material 4A, raw material, which is an aqueous solution containing zirconium oxychloride ($ZrOCl_2 \cdot 8H_2O$) and lead nitrate ($Pb(NO_3)_2$), and a KOH(8N) solution, which is a mineralizer, are placed in a Teflon container (not shown) and agitated. The piezoelectric characteristic of the PZT thin films 5 is determined by the composition ratio of lead titanate and lead zirconate. Thus, the mol ratio between the zirconium oxychloride and the lead nitrate is determined in accordance with the piezoelectric characteristic of the PZT thin films 5, which are formed later.

[0027] Afterward, with the base material 4A arranged at the upper portion of a pressure vessel (not

shown), an aqueous solution containing zirconium oxychloride ($ZrOCl_2 \cdot 8H_2O$) and lead nitrate ($Pb(NO_3)_2$), and a KOH(8N) solution are mixed in the pressure vessel. The mixture is heated and pressurized while being agitated at a speed of 300rpm. Pressurizing refers to pressurizing using the vapor pressure of the heated solution. The heated and pressurized state lasts for 48 hours under a temperature of 150°C. Consequently, PZT seed crystals (crystal nucleus) are formed on both sides of the base material 4A in a supersaturated state. After the formation of the seed crystals, the base material 4A is removed from the pressure vessel, washed with water, and dried.

[Second Stage]

[0028] Subsequently, the base material 4A, on which the seed crystals are formed, raw material, which is an aqueous solution containing zirconium oxychloride ($ZrOCl_2 \cdot 8H_2O$) and lead nitrate ($Pb(NO_3)_2$), a solution containing titanium tetrachloride ($TiCl_4$) and potassium hydroxide (KOH(4N)), which serves as a mineralizer, are placed in a Teflon container (not shown) and agitated. The mol ratio between zirconium oxychloride and lead nitrate is determined in accordance with the PZT piezoelectric characteristic.

[0029] Then, with the base material 4A arranged at the upper portion of a pressure vessel (not shown), an aqueous solution containing zirconium oxychloride ($ZrOCl_2 \cdot 8H_2O$) and lead nitrate ($Pb(NO_3)_2$), and a solution containing titanium tetrachloride ($TiCl_4$) and KOH(4N) are mixed in the pressure vessel, and heated and pressurized while being agitated at a speed of 300rpm. Pressurizing refers to pressurizing using the vapor pressure of the heated solution. This treatment lasts for 48 hours under a temperature of 120°C. Consequently, a PZT thin film 5 having the predetermined thickness (in the present embodiment, several tens of micrometers) is formed on both sides of the base material 4A in a supersaturated state (refer to Fig. 4). After the formation of the PZT thin film 5, the base material 4A is removed from the pressure vessel, washed with water, and dried. Afterward, the mask M is removed.

[0030] As shown in Fig. 5, an electrode film 6A is then formed on each side of the base material 4A, which includes the PZT thin film 5, by carrying out a physical film formation process, such as sputtering or vacuum deposition. As shown in Figs. 6 and 7, patterning is then performed to remove unnecessary sections of the electrode films 6A in order to obtain a plurality of piezoelectric devices 2 (three in the present embodiment) from the base material 4A. As a result, in the present invention, three rows of electrode films 6, each extending in a direction indicated by arrow "A", are formed on the PZT thin film 5 on each side of the base material as shown in Fig. 7. Each row includes two electrode films 6, which have the same area and the same shape. As shown in Fig. 7, the electrode films 6 are

arranged on both sides of the titanium substrate 4 such that they are opposed to each other with the base material 4A arranged in between.

[0031] As shown in Fig. 8, the unnecessary sections of the base material 4A are removed. Subsequently, two base materials 4A, which include the PZT thin film 5 and the electrode films 6 are faced toward each other. Rectangular column-like insulating spacers 3, which are made from synthetic resin, are then arranged between the two base materials 4A.

[0032] As shown in Fig. 9, the base materials 4A and the spacers 3 are fixed to one another with an adhesive agent, which increases rigidity after hardening, to form a parallel plate structure 1A. The structure 1A is formed by interconnecting independent structure bodies.

[0033] The structure 1A is then cut along the dotted lines between each row of electrode films 6 to separate the structure 1A into independent parallel plate structures 1 as shown in Fig. 10. The cutting is performed by electric discharge machining or laser cutting.

[0034] As described above, the application of voltage having opposite polarities to the upper and lower portions of the piezoelectric devices 2 deforms the structure 1 as shown in Figs. 2(a) or 2(b). This deformation mode will hereafter be referred to as a parallel plate actuation mode.

[0035] A parallel plate structure 21, which is provided with bimorphs, is shown in Fig. 11 as a comparative example. In the drawing, like numerals are used for like elements of the structure 1 of the present embodiment.

[0036] The structure 21 of the comparative example differs from the structure 1 of the present embodiment in that only one electrode film 26 is formed on each side of a titanium substrate 4. Power sources B1, B2 are connected to the structure 21 in a series. The positive terminal of each power source B1 is connected to the left electrode film 26 of the associated piezoelectric device 2. The negative terminal of each power source B2 is connected to the right electrode film 6 of the associated piezoelectric device 2. The contact between the power sources B1, B2 is connected to the associated titanium substrate 4. In the comparative example, the polarity direction of the PZT thin-films 5 is the same as that shown in Fig. 1(a).

[0037] When the lower end of the structure 21 is fixed to a base (not shown) and voltage is applied as shown in Fig. 11, the portion of the PZT thin-film 5 to which an electric field is applied in the polarity direction contracts, while the portion of the PZT thin-film 5 to which an electric field is applied in the direction opposite the polarity direction expands. Accordingly, the structure 21 deforms to the left as viewed in Fig. 11.

[0038] On the other hand, the application of voltage having the opposite polarity to the piezoelectric devices 2 contracts the right PZT thin-film 5 of each piezoelectric device 2 and expands the left PZT thin-film 5 of each

piezoelectric device 2. Accordingly, the structure 21 deforms to the right as shown in Fig. 12. The electrode films 26 of the comparative example are not shown in Fig. 12. The contracted portions 5 of the PZT thin-films

5 are shown by the hatch lines extending downward from right to left, and the expanded portions are shown by the hatch lines extending downward from left to right.

[0039] When the same voltage is applied to the structure 1 and the structure 21, the deformation amount of the structure 1 is greater than that of the structure 21. The reasons for this will be described with reference to Figs. 13 and 14. Fig. 13 shows the deformation of the structure 1 of the present embodiment, while Fig. 14 shows the deformation of the structure 21 of the comparative example.

[0040] In Fig. 14, "a" denotes deformation during application of voltage when the insulating spacer 3 at the free end does not exist. Attachment of the insulating spacer 3 interferes with the deformation of the piezoelectric devices 2 and changes the deformation to "c" ($c < a$). In Fig. 13, the two electrodes results in the deformation being $a/2$ at the fixed end of the piezoelectric device 2. Furthermore, the free end of the piezoelectric device 2 deforms in the same manner as the fixed side. The free end side deformation is thus $a/2$ and the total deformation of the structure 1 is a . Accordingly, the deformation amount of the structure 1 of the present embodiment is greater.

[0041] In the present embodiment, the PZT thin-film 5 is thin with a thickness of several tens of micrometers. This, decreases the size of the piezoelectric devices 2, which in turn, decreases the size of the structure 1.

[0042] The structure 1 of the present embodiment is a parallel plate structure, in which a pair of bimorphs, or piezoelectric devices 2, and spacers are superimposed. Thus, twist resistance is improved.

[0043] The fabrication method of the structure 1 of the present embodiment efficiently manufactures structures 1 having uniform quality since the hydrothermal process forms the PZT thin-film 5 and the electrode films 6 simultaneously on a plurality of substrates 4. Since spacers are used to fix the bimorphs to each other, the formation of the structure 1 is simplified.

[0044] The embodiment according to the present invention may be modified as described below.

[0045] The insulating spacers 3 may be replaced by spacers made of a non-insulating material, such as metal, as long as the piezoelectric devices 2 are insulated from each other. In this case, the spacers are fixed to the piezoelectric devices 2 using other means such as welding. Furthermore, the electrode films 6 may be formed from other metals, such as gold (AU), instead of aluminum.

[0046] The thickness of the electrode films 6, the PZT thin-films 5, and the substrates 4 is not limited to the above values and may be changed as required.

[0047] In the above embodiment, three bimorphs are obtained from the same base material 4A. However,

two or less or four or more bimorphs may be obtained from the same material.

Claims

1. A parallel plate structure including a pair of parallel bimorphs (2), and a spacer (3) for connecting the bimorphs (2), wherein each bimorph (2) has a titanium substrate (4), the titanium substrate (4) having a first surface and a second surface, which is located on the opposite side of the first surface, and a PZT thin-film (5) formed on each of the first and second surfaces, wherein the parallel plate structure is characterized by:

a plurality of spaced electrodes (6) formed on each PZT thin-film (5) and extending in the same direction.

2. The parallel plate structure according to claim 1 characterized in that the number of electrodes (6), which includes first and second electrodes (6), on each of the first and second surfaces is two.

3. The parallel plate structure according to claim 2 characterized in that the first electrode (6) extends from one end to a substantially middle portion of the associated PZT thin-film (5), and the second electrode (6) extends from the other end to the substantially middle portion of the associated PZT thin-film (5).

4. The parallel plate structure according to any one of claims 1 to 3 characterized in that the PZT thin-film (5) is formed via a hydrothermal process.

5. The parallel plate structure according to any one of claims 1 to 3 characterized in that the spacer (3) is arranged at one end of the bimorphs (2), and a further spacer (3) is arranged at the other end of the bimorphs (2), wherein both spacers (3) are insulating bodies.

6. A method for fabricating a parallel plate structure, wherein the method is characterized by the steps of:

preparing a titanium substrate (4);
 forming a PZT thin-film (5) on a first surface of the titanium substrate (4) and a second surface, which is located on the opposite side of the first surface, by employing a hydrothermal process;
 producing a bimorph (2) by arranging a plurality of electrodes in the same direction on each PZT thin-film (5); and
 fixing a pair of bimorphs (2), which are arranged parallel to and opposed to each other,

with a spacer (3).

7. The method according to claim 6 characterized in that the step for producing a bimorph (2) includes forming rows of electrodes (6) extending in the same direction on each PZT thin-film (5), and subsequently cutting between each row.

8. The method according to any one of claims 6 and 7 characterized in that the hydrothermal process includes the steps of:

forming seed crystals on the first and second surfaces of the titanium substrate (4); and
 growing PZT crystals on the first and second surfaces of the titanium substrate (4).

9. The method according to claim 8 characterized in that the seed crystal forming step includes the step of pressurizing and heating while agitating a mixture of lead nitrate solution, zirconium oxychloride, and a mineralizer.

10. The method according to claim 8 characterized in that the crystal growing step includes the step of pressurizing and heating while agitating a mixture of lead nitrate solution, zirconium oxychloride, and a mineralizer.

11. The method according to any one of claims 9 and 10 characterized in that the pressurizing is performed by the vapor pressure of the heated mixture.

12. The method according to any one of claims 6 to 11 characterized in that a mask is applied to predetermined sections of the titanium substrate (4) before the step of forming the PZT thin-film (5).

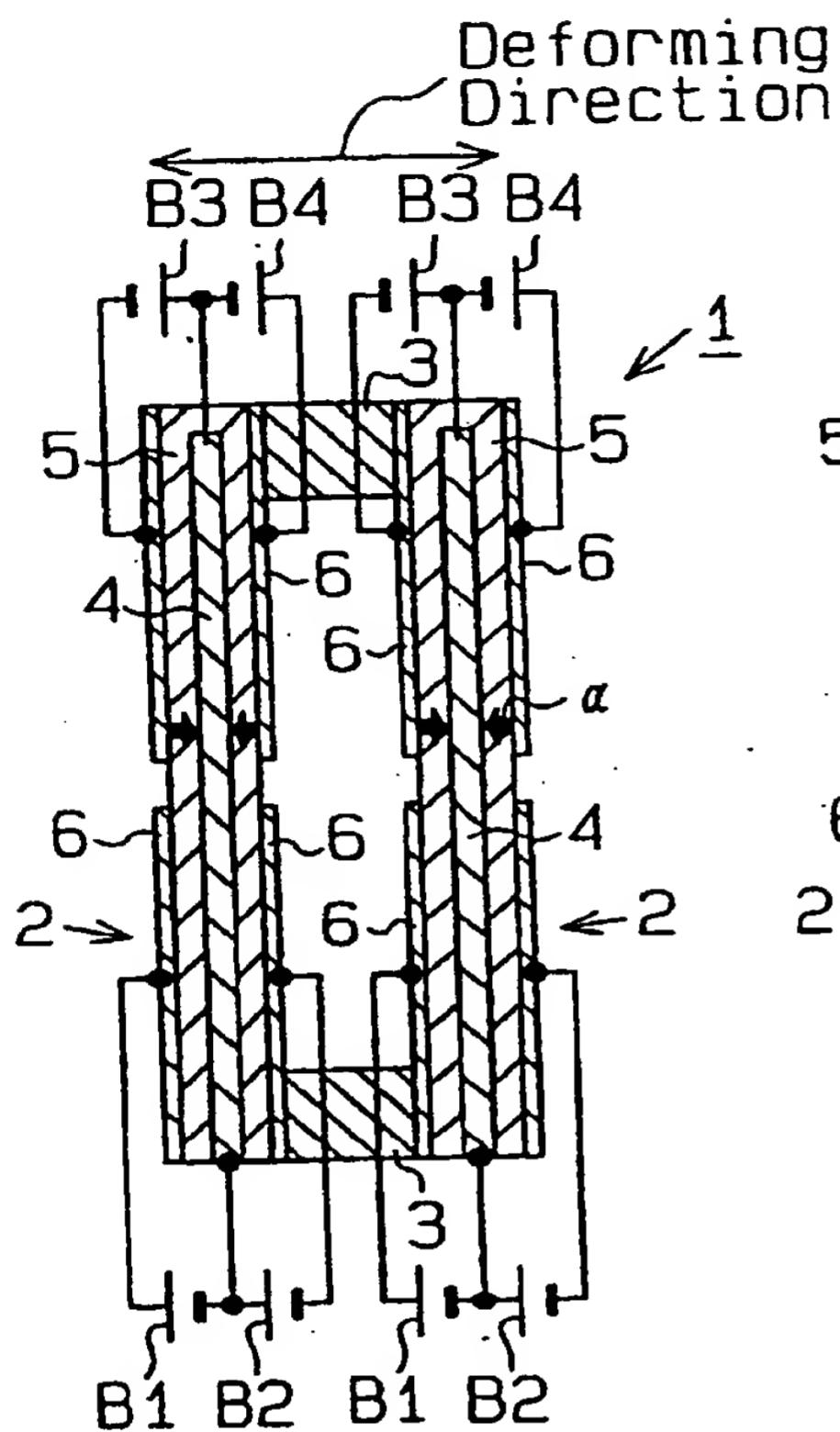
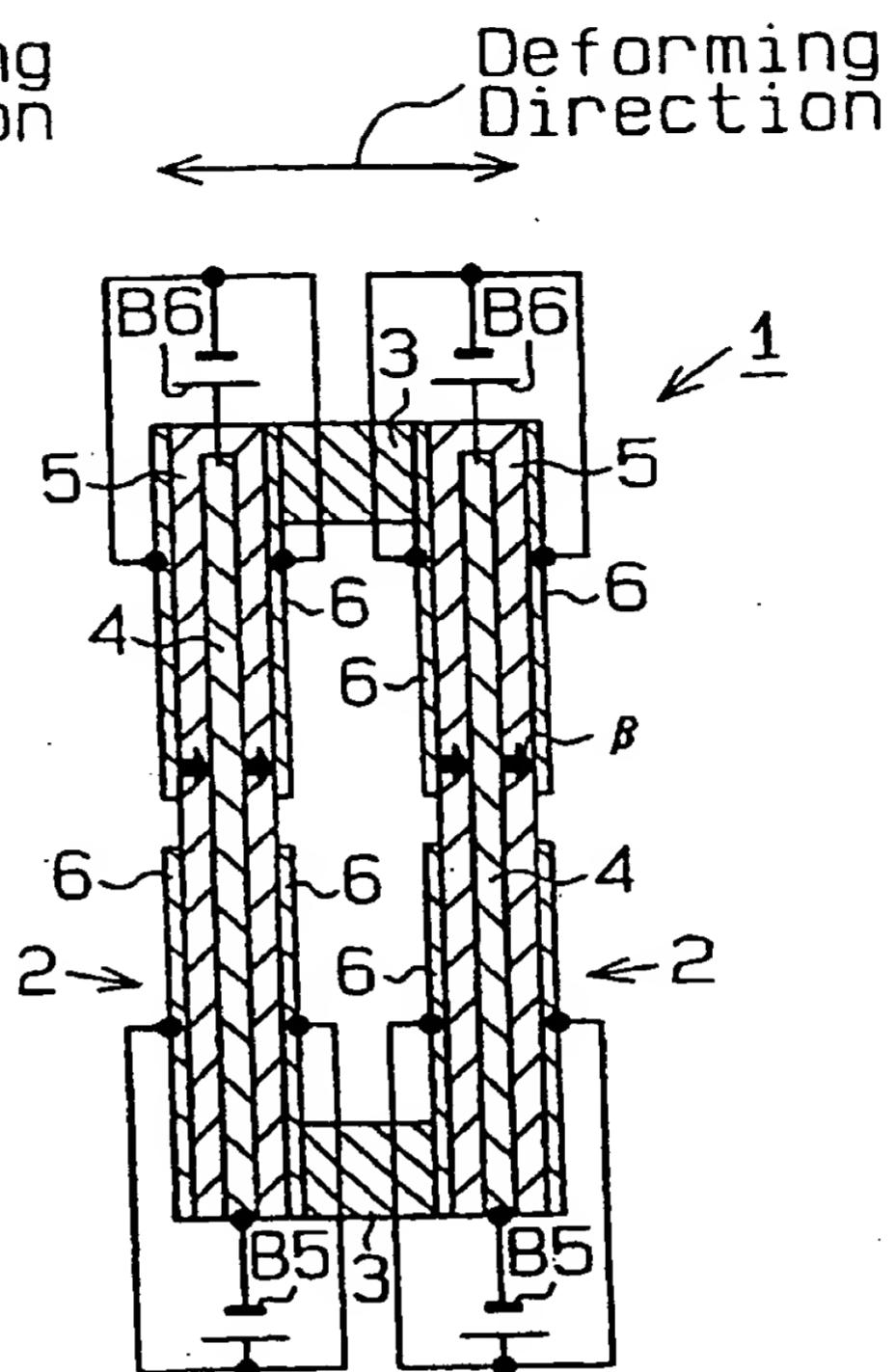
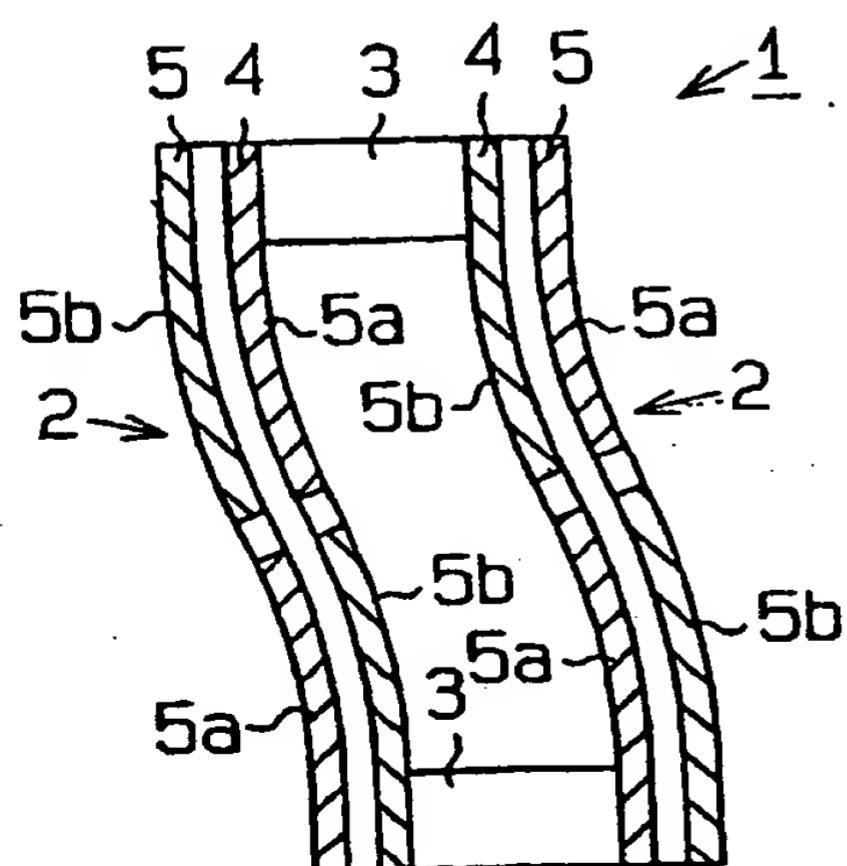
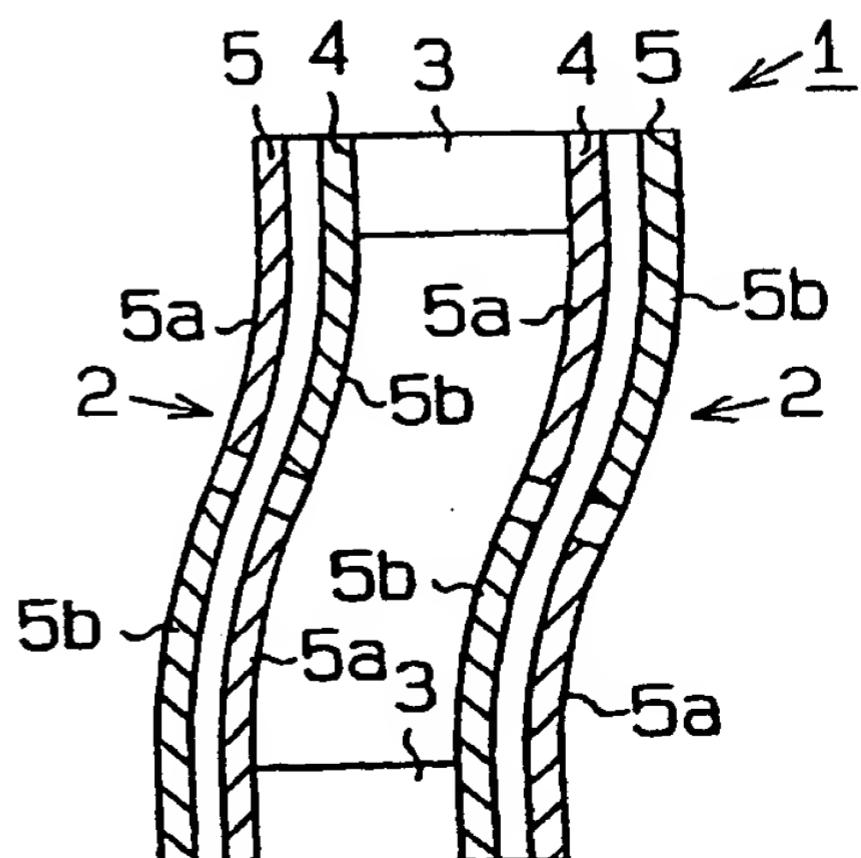
Fig.1 (a)**Fig.1 (b)****Fig.2 (a)****Fig.2 (b)**

Fig.3

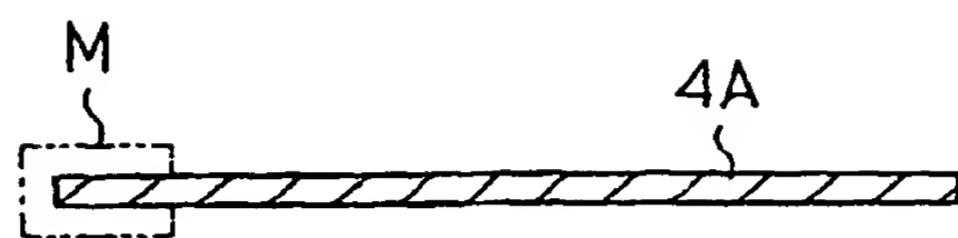


Fig.4

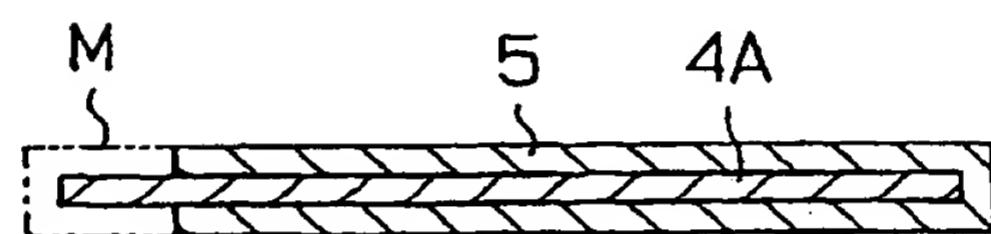


Fig.5

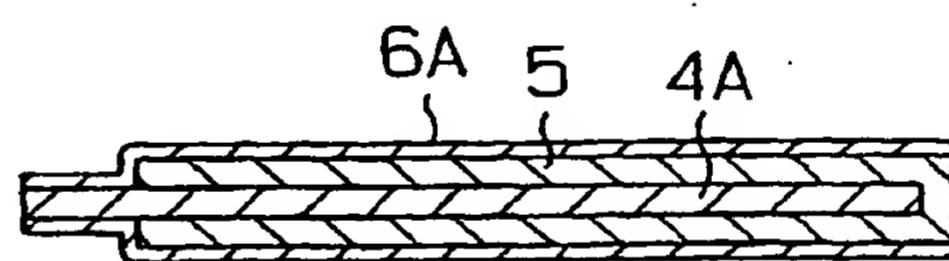


Fig.6

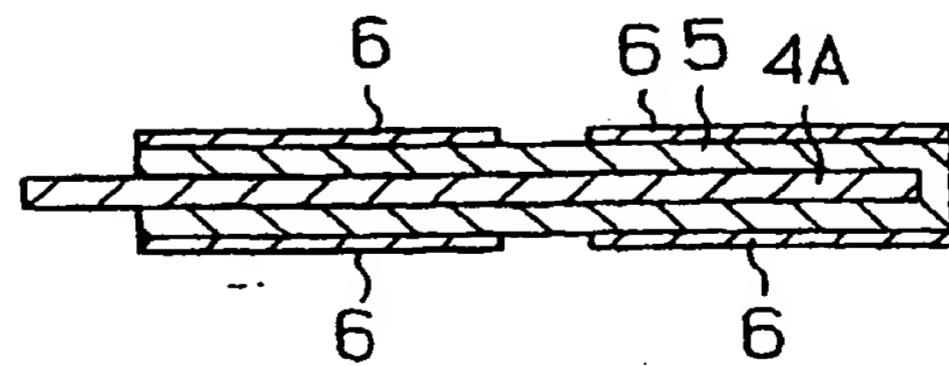


Fig.7

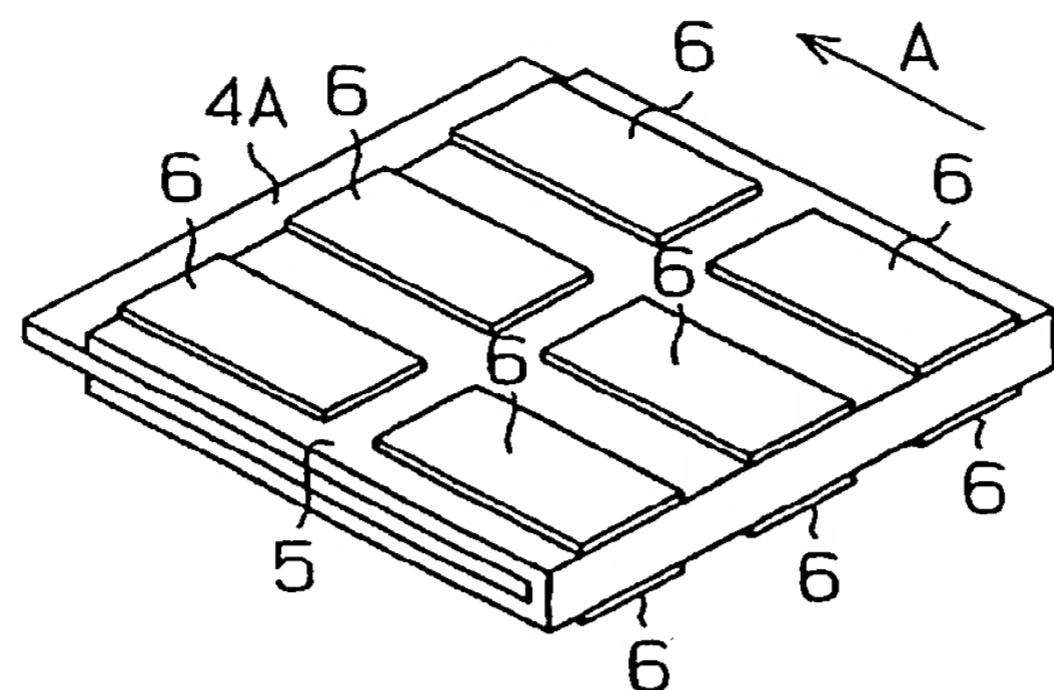


Fig.8

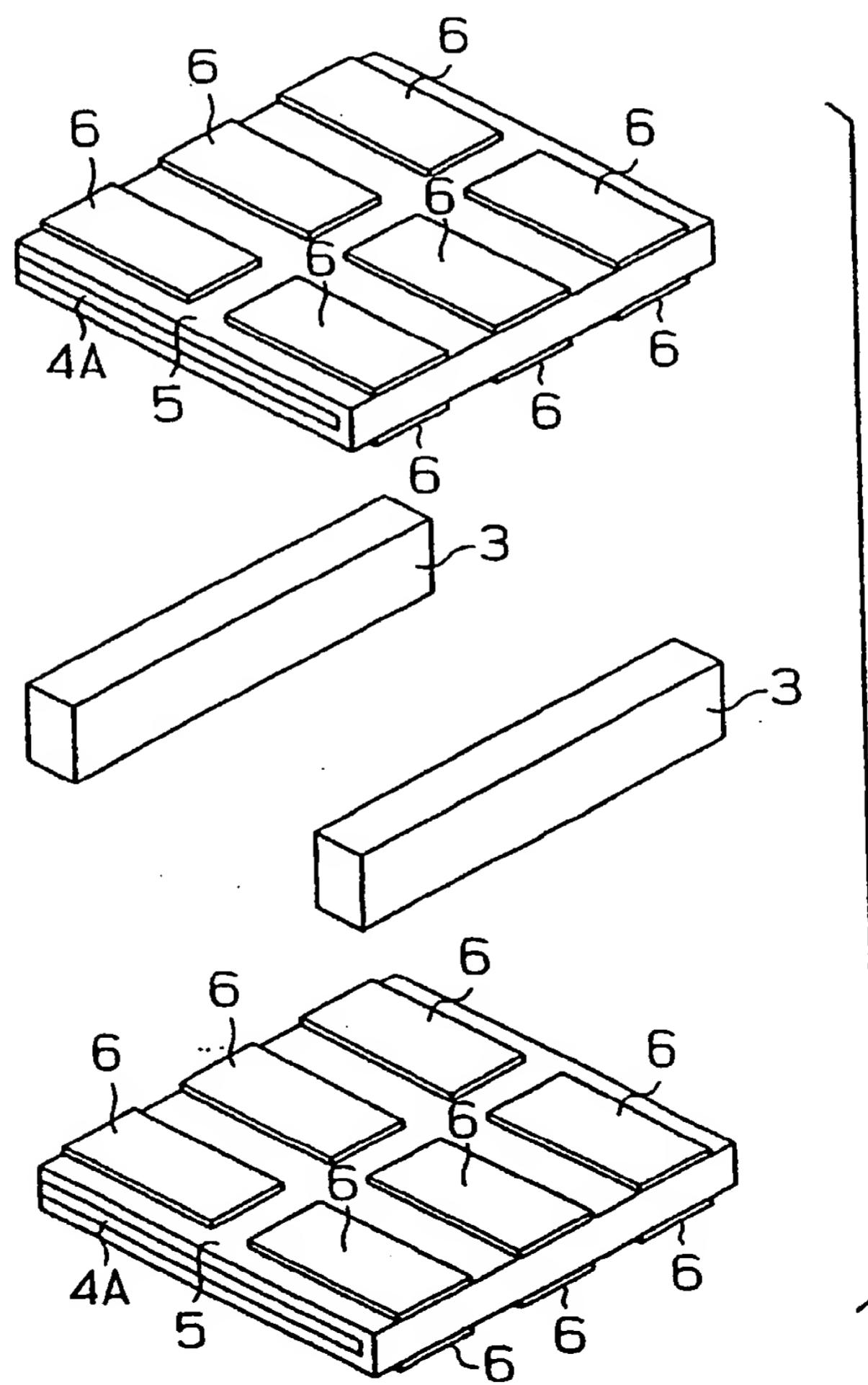


Fig. 9

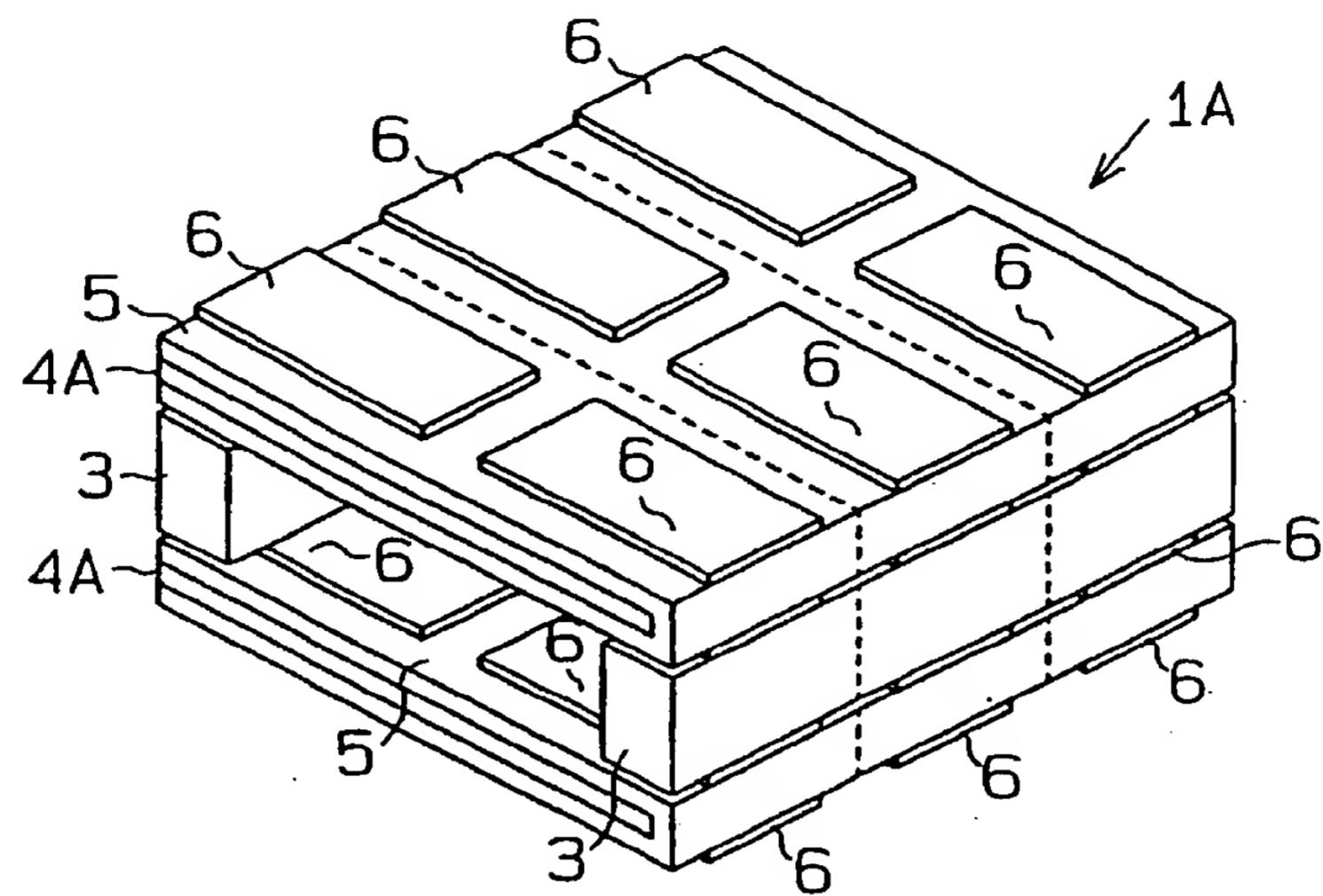


Fig. 10

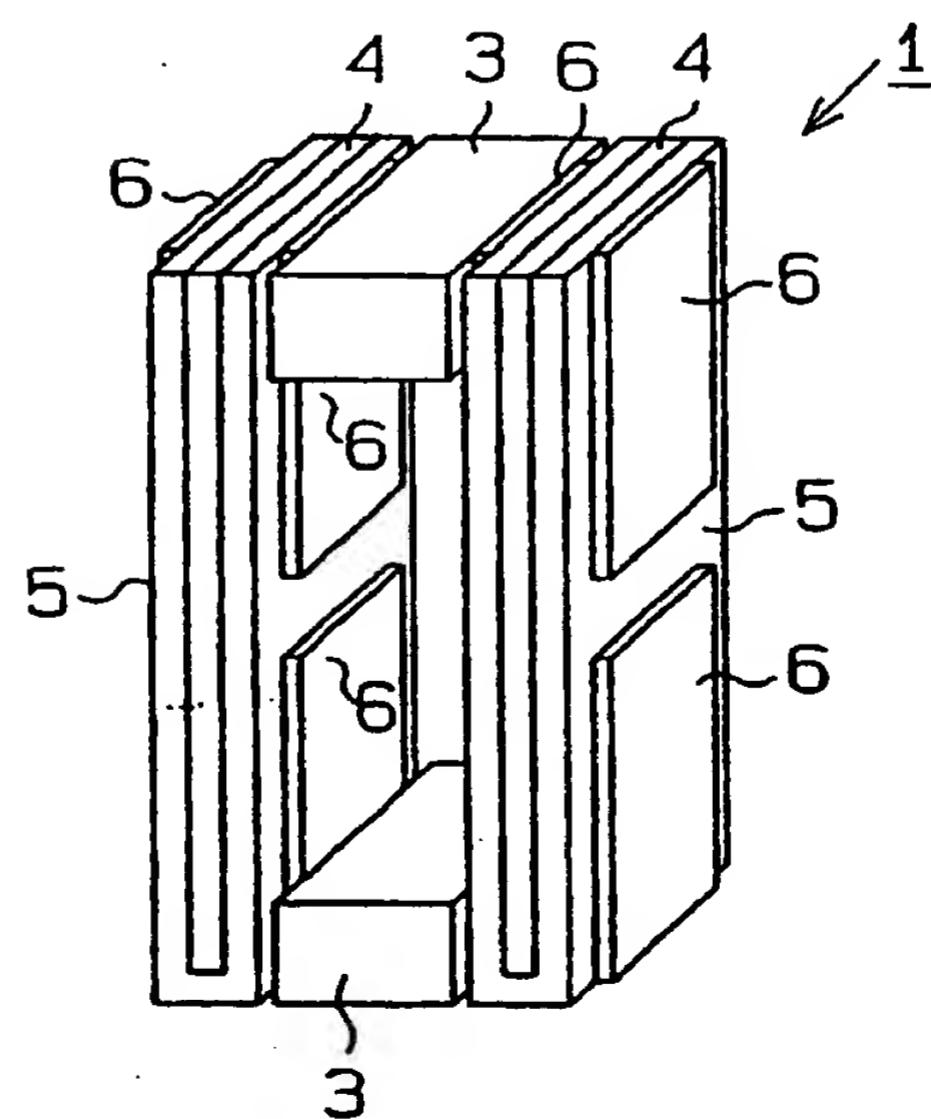


Fig.11

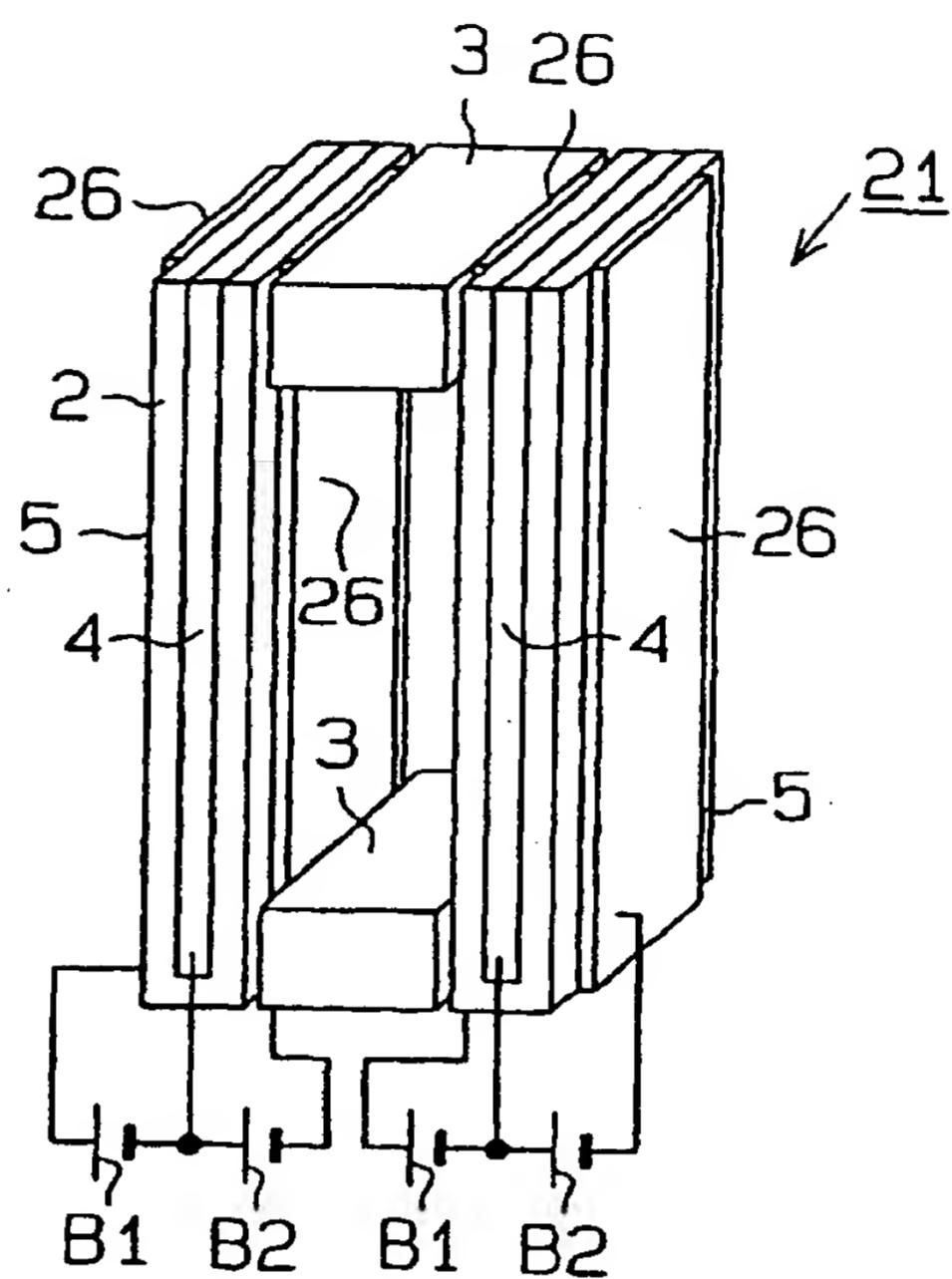


Fig.12

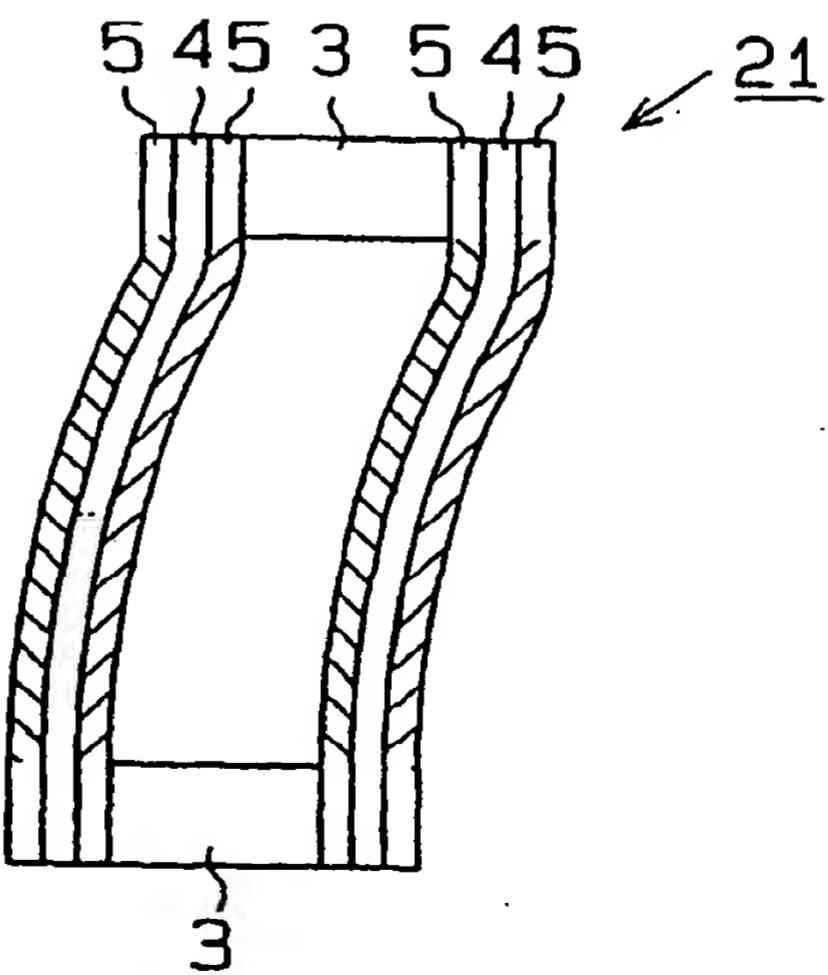


Fig.13

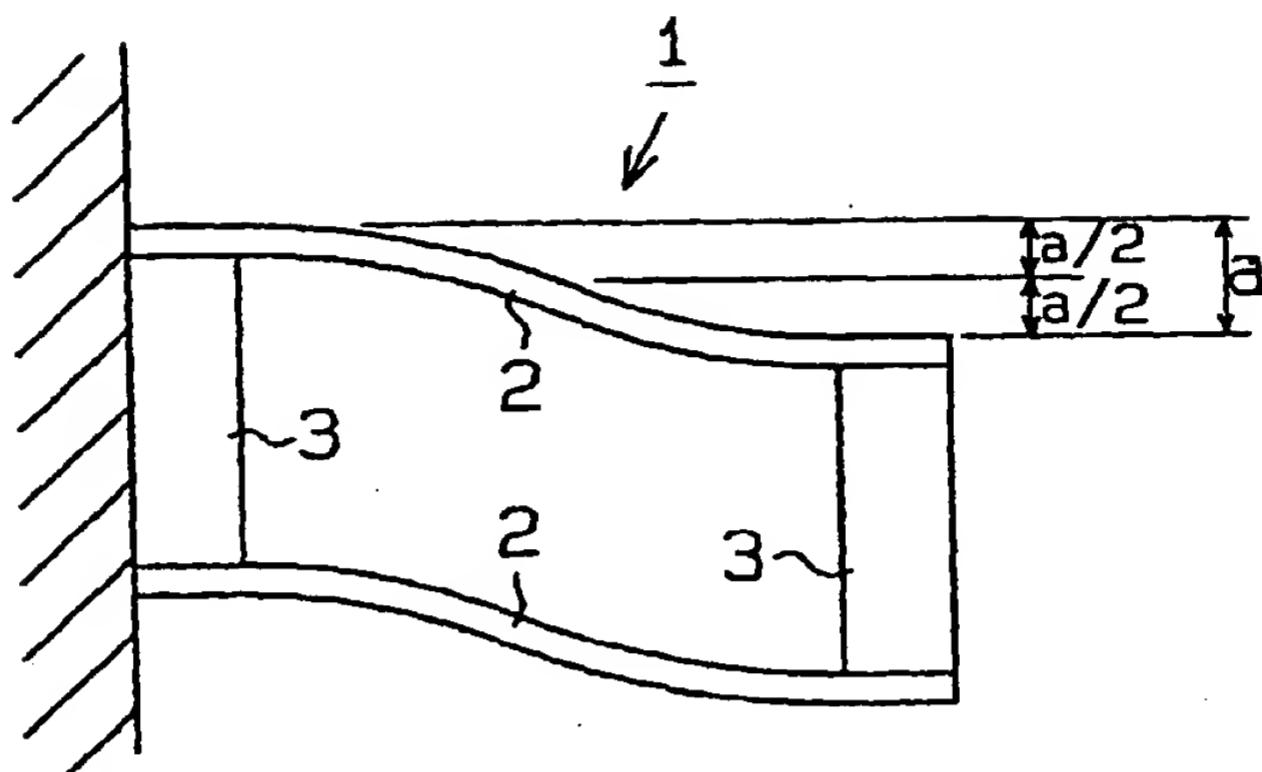
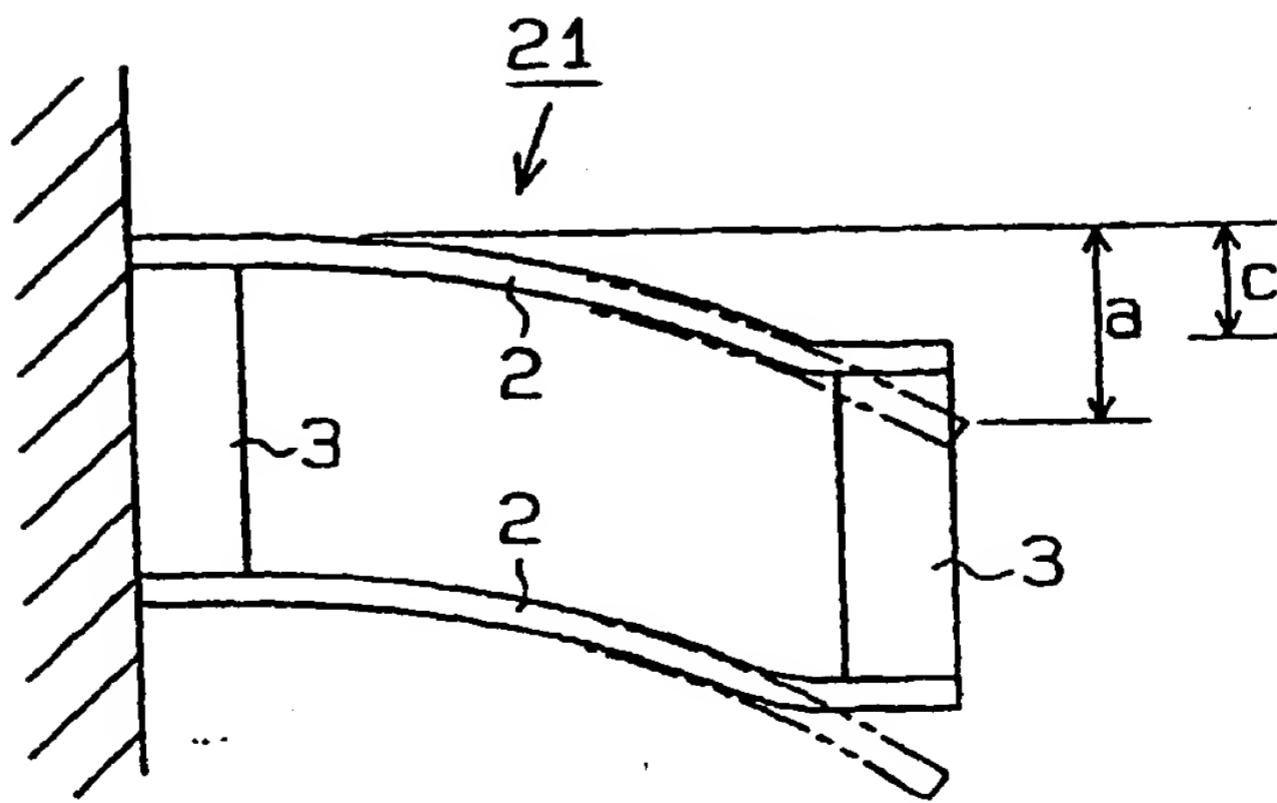


Fig.14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP98/02991

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁶ H01L41/09, 41/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl⁶ H01L41/09, 41/24Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1998 Toroku Jitsuyo Shinan Koho 1994-1998
Kokai Jitsuyo Shinan Koho 1971-1998 Jitsuyo Shinan Toroku Koho 1996-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 59-229733, A (Sharp Corp.), 24 December, 1984 (24. 12. 84) (Family: none)	1-12
Y	JP, 59-111060, Y2 (Tokin Corp.), 26 July, 1984 (26. 07. 84) (Family: none)	1-12
Y	JP, 62-146426, A (Asahi Optical Co., Ltd.), 30 June, 1987 (30. 06. 87) (Family: none)	1-12
Y	JP, 04-65470, A (Matsushita Electric Industrial Co., Ltd.), 8 June, 1992 (08. 06. 92) (Family: none)	1-12
Y	JP, 05-259525, A (Ube Industries, Ltd.), 8 October, 1993 (08. 10. 93) (Family: none)	1-12
Y	JP, 08-293631, A (Tokin Corp.), 5 November, 1996 (05. 11. 96) (Family: none)	1-12

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier document but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 13 October, 1998 (13. 10. 98)	Date of mailing of the international search report 20 October, 1998 (20. 10. 98)
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Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)